DOCUMENT RESUME

ED 278 538 SE 047 698

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TITLE Creating an Atmosphere of Intellectual Development in the Middle School Science Class.
PUB DATE Jun 86
NOTE 43p.; Exit Project, Indiana University, South Bend.
PUB TYPE Reports - Descriptive (141) -- Reference Materials - Bibliographies (131) -- Information Analyses (070)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Abstracts; *Academic Achievement; *Cognitive Development; Elementary Education; *Elementary School Science; Learning Strategies; Literature Reviews; *Middle Schools; *Piagetian Theory; Science Education; *Science Instruction; Skill Development; Teaching Methods
IDENTIFIERS *Science Education Research

ABSTRACT

A review of the research on the cognitive development of middle school students is presented and ways of promoting intellectual growth in middle school science classrooms are offered. The annotations in this review are organized into four sections. The first part focuses on the research on the cognitive development of the middle school student. The relationship of cognitive development to students' science achievement is discussed in the second part. The third section investigates the possibility of fostering intellectual development within science classrooms by reviewing studies that have tried to determine the instructional methods needed to encourage intellectual development. The final section of the annotations discusses techniques that aim to promote students' intellectual development. A glossary of 20 terms is included. A synthesis of the studies, the implications for instruction, specific recommendations, and a bibliography are also provided. (ML)

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CREATING AN ATMOSPHERE OF INTELLECTUAL DEVELOPMENT IN THE MIDDLE SCHOOL SCIENCE CLASS

by

Janet L. Swigert

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Submitted in partial fulfillment of the requirements

for the course S591--Exit Project

Indiana University at South Bend

June, 1986

SE 047 698

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INTRODUCTION

The traditional teaching methods of science education have been text reading, memorization, and recall of information. These methods have caused many students to dislike science before they really understand it, to fail to learn essential scientific principles and to miss the excitement and fun of science.

One purpose of education is intellectual development (Renner, 1980, p.193.). The curricula, and the methods of teaching that curricula, need to have a theory base that will ultimately lead to that goal or purpose (Renner, 1980, p.193). This annotated bibliography investigates the learning theory and intellectual development model of Jean Piaget as a theory base for science education. Herron suggests the importance in this study in his statement,

> If Piaget's notions are correct, then much of the time spent on science instruction in elementary and middle schools today is wasted. Even worse, if we continue to insist that students learn ideas that they are unable to understand because they lack the logical structures necessary for understanding, they have little choice but to resort to rote memory. As a result, they develop poor study habits, poor attitudes toward school and low self image. (Herron, 1978, p. 593).

A question posed by Renner and Phillips, with an addition to make it appropriate here, is the focus of this paper: What aspects of (middle school science) teaching would be changed in an atmosphere devoted to intellectual development as opposed to one of memorization and recall?

Collette and Chiappetta discribed Jean Piaget's theory of

four major stages of cognitive development. The middle school student, ages 11-14, would be classified as either concrete operational, formal operational, or in transition between the two stages. Further explained by Collete and Chiappetta is that the concrete operational stage begins around age six and continues into the teen years and also into adulthood for some individuals. The ability to order, classify, add, subtract, multiply, and divide are developed during this stage. The ability to conserve is also developed.

Inhelder and Piaget stated that,

> Formal thought is more than verbal reasoning (propositional logic). It also entails a series of operational schemata which appear along with it; these include combinatorial operations, propositions, double systems of reference, a schema of mechanical equilibrium (equality between action and reaction), multiplicative probabilities, correlations, etc.... (Inhelder and Piaget, 1958, p. xxii).

By studying the research done by Piaget and others that have related Piaget's theories with science education, teachers are able to develop better perspectives and fresh approaches to the teaching of science to the middle school student.

STATEMENT OF THE PROBLEM

The middle school science class should be a place of intellectual development, not a scene of memorization and rote recall.

PURPOSE OF THE STUDY

The purpose of this study was to review research on cognitive development of the middle school student and to discover ways of promoting intellectual development in the middle school science classroom. By reviewing research by Piaget and other more recent studies, one can make comparisons and formulate conclusions to help the middle school teacher develop the appropriate instructional materials and methods needed to enhance the intellectual development of the middle school student in the science classroom.

ORGANIZATION OF THE STUDY

This review of research has been divided into four parts. The first part is the review of research on cognitive development of the middle school student. The relationship of the cognitive development to the student's science achievement is discussed in the second part.

The third section of this review investigates the possibility of fostering intellectual development within the science classroom

by reviewing research that has tried to determine the instructional methods needed to encourage intellectual development. The final section discusses techniques that will promote the intellectual development in the classroom. The annotations have been arranged into the four parts of organization and then alphabetized within those sections.

LIMITATIONS OF THE STUDY

The research on this subject was limited in several ways. First, there was little empirical research written on this topic. Second, the research reviewed was limited in scope. Most of the research concerned with fostering intellectual development studied only one area of formal thinking, such as control of variables in Lawson and Wollman's study and Howe and Mierzwa's study. Third, a number of the research studies had limited samples, and therefore led to questionable implications and conclusions by the researchers. Finally, much of the research had been done using older high school and college students rather than middle school students.

GLOSSARY

Accommodation - Accommodation is the process of reaching out and adjusting to new and changing conditions in the environment, so that preexisting patterns of behavior are modified to cope with new information or feedback from external situations (Pulaski, 1980, p. 231).

Adaptation - This is a biological mode of functioning that characterizes all forms and levels of life. It consists of the dual processes of assimilation and accommodation, which go on continuously (Pulaski, 1980, p. 231).

Assimilation - This is the process of taking in from the environment all forms of stimulation and information, which are then organized and integrated into the organism's existing forms or structures, thus creating new structures (Pulaski, 1980, p. 231).

Calorimetric - This is an adjective form of calorimetry, which is the process of measuring the quantity of heat (Webster's New World Dictionary, 1960, p. 208).

Cognitive Development - According to Piaget, cognitive development is the development in the child's thought process through his adaptation to the environment and assimilation of information (Good, 1973, p. 176).

Concrete Materials - (arith) These are actual objects that are used with pupils in activities and which provide opportunity for the development of number concepts: for example, two halves of an apple might be used to illustrate the concept that two halves are equal to one whole (Good, 1973, p. 352).

Conservation - This is the ability to understand that objects or quantities are "conserved" and remain constant despite changes in their appearance (e.g., one cup of milk is the same amount whether poured into a tall, thin glass or a wide shallow bowl) (Pulaski, 1980, p. 232).

Disequilibrium - This is the state of imbalance which includes the discomforting inner conflict between opposing interpretations that provides the motivation to find a solution. This solution restores the intellectual balance and inner contentment (Labinowicz, 1980, p. 36).

Equilibration - This is the dynamic, continuous self-regulating process of balancing the changes brought about by constant assimilation and accommodation in order to arrive at a "steady state" or equilibrium. It is the organizing factor underlying all biological and intellectual development (Pulaski, 1980, p. 233).

Exposition Teaching - This is a style of teaching where the teacher and printed teaching materials tell the student what they are expected to learn. (Schneider and Renner, 1980, p.503).

Figurative Knowledge - This refers to aspects of knowledge that are static, focused on the configurations of objects, on their perceived appearance. Figurative and operative knowledge represent different aspects of the same knowing process. (Pulaski, 1980, p. 233).

Hierarchical Classification - This term refers to a grouping of objects based on two or more attributes in a series of successive terms of different rank; e.g., "schools" may be divided into "teachers" and "students" with "students" subdivided into " elementary," "secondary," "college," etc., and "teachers" subdivided into "experienced," "inexperienced," etc. (Yussen and Santrock, 1978, p. 591).

Inquiry Approach - (sci ed) This is a particular technique or stategy for bringing about learning of some particular science content by encouraging a student to be inquisitive and curious and to ask questions and try to find answers for himself (Good, 1073, p. 303).

Integrated Science Process Skills - These skills arise from the science education literature and include those abilities used when identifying variables, hypothesizing, operationally defining and designing experiments and graphing and interpreting data (Yeany, Yap and Padilla, 1986, p. 277).

Intellectual Development - For Piaget, it is the process of restructuring knowledge: The process starts with a structure or a way of thinking proper to one level; some external disturbance or intrusion on this ordinary way of thinking creates a conflict and disequilibrium; the person compensates for this disturbance and solves the conflict by means of his own intellectual activity; the final state is a new way of thinking and structuring and satifaction, in short, a state of new equilibrium (Labinowicz, 1980, p. 35).

Internalization - This is the gradual dissociation between external actions and the mental representations that replace them; e.g., the action of counting aloud while touching each of five blocks becomes internalized as a numerical experience of a series of five (Pulaski, 1980, p. 234).

Operations - This refers to the internalized activities of the mind, as opposed to the sensory-motor or physical activities of the body. They are characterized by logical thought processes that are organized, structured, reversible, and can be generalized (Pulaski, 1980, p. 234).

Operative Knowledge - This relates to action; dynamic, transformational aspects of knowledge at any level from sensory-motor to formal (Pulaski, 1980, p. 234-235).

Scheme - pl. schemata (in Piaget) - This refers to organized patterns of behavior, both physical and intellectual (Garbarino, 1985, p. 613).

Symbolic Representation - This refers to the use of symbols to represent external reality (Pulaski, 1980, p. 236).

ANNOTATIONS

THE COGNITIVE DEVELOPMENT OF THE MIDDLE SCHOOL STUDENT

Chiappetta, Eugene L. "A Review of Piagetian Studies Relevant to Science Instruction at the Secondary and College Level." Science Education 60.2 (1976): 253-261.

This paper was a review of studies which had done research on the developmental level of adolescents and young adults. It also reviewed research on cognitive development and its relationship to science achievement. Finally, the author included a discussion of the research and implications for science teaching. In this review the author stated that, in general, research shows that most adolescents operated at the concrete operational level on their understanding of science subject matter.

Karplus, Robert, Elizabeth Karplus, Marina Formisano, and Albert Christian Paulsen. "A Survey of Proportional Reasoning and Control of Variables in Seven Countries." Journal of Research in Science Teaching 14.5 (1977): 411-417.

In this study, the researchers chose a sample of students ages thirteen - fifteen years old from seven countries: Denmark, Sweden, Italy, U.S., Austria, Germany, and Great Britain. They tested the students to determine their use of proportional reasoning and control of variables. In the conclusion, they suggested that a substantial fraction of students lack ability to articulate proportional reasoning and/or control of variables. Even though the differences from country to country were small, they were significant and showed that teaching can be an influence on the development of reasoning by students in this age range. Therefore, they suggested that development of reasoning patterns should be an important objective of teaching programs for this age group.

Kolodiy, George Oleh. "Cognitive Development and Science Teaching." Journal of Research in Science Teaching 14.1 (1977): 21-26.

This study compared the cognitive levels of three groups of subjects who were at three different stages of educational process. The study tried to determine whether education might exert an influence on cognitive development. In the discussion, the author suggested that if an educator accepts the very basic tenets of what Piaget says, he can then proceed to develop educational materials based on those principles. He suggested the importance of material having relevance to what is already known and also being novel enough to present conflict and mental disequilibrium.

Findings suggested that even among above-average students there exists a wide variability in cognitive functioning, implying a need for learning experiences to be more individualized. Kolodiy suggested the learning experiences need to be less lecture oriented and emphasize more concrete activities with interaction among students to help present disequilibrium, leading to accommodation.

Lawson, Anton E. "Combining Variables, Controlling Variables and Proportion: Is there a Psychological Link? Science Education 63.1 (1979): 67-72.

The purpose of this study was to determine relationships among individual performances on three formal operations tasks: the chemical combination task, which required the subjects to generate all possible combinations of colorless liquids to effect a color change in reactants, the bending rod task, which required the isolation and control of variables, and the balance beam task, which involved quantitative proportional relationships. The sample included twenty-eight students, the average age being 12.4 years.

The results of the test supported the Piagetian hypothesis of general stages of intellectual development. It also emphasized the diversity of intellectual functioning at this age level and the teaching implications because of that variability.

Lawson, Anton E., Robert Karplus, and Helen Adi. " The Acquisition of Proportional Logic and Formal Operational Schemata During the Secondary School Years." Journal of Research in Science Teaching 15.6 (1978): 465-478.

The issue of this study was that of developing a sound psychological theory and set of teaching principles to best promote the development of students' reasoning abilities. The sample included 507 students spanning an age range of 11.5 to 20 years. The researchers administered a seven-item, pencil-paper test. Five items required use of formal operational schemata of proportion, probabilities, and correlations. Two items required the use of common rules of propostional logic.

The results showed an increase in the percentage of success with school grade. However, there was a lack of ability to successfully apply the rules of propositional logic at all age levels.

Lawson, Anton E. and John W. Renner. "A Quantitative Analysis of Responses to Piagetian Tasks and Its Implication for Curriculum." Science Education 58.4 (1974): 545-559.

The purpose of this study was to determine if a battery of Piagetian- styled tasks could be used and scored quantitatively to determine the percentage of the school population in grade seven through thirteen that had entered the stage of formal thought. There were three samples in this report. The first sample was of students from grade seven through twelve. A battery of six Piagetian-styled tasks was administered with results of 588 interviews showing an extremely large percentage of students responding concretely. The second sample tested 143 college freshmen with results showing only 22% classified as formal thinkers. The third sample involved 134 Biology, Chemistry, and Physic students. Those taking Chemistry and Physics showed only 4% and 3% were concrete thinkers, respectively. The results of this study differed with Piaget in the age at which an individual enters the formal operational stage.

Nussbaum, Joseph. "Children's Conceptions of the Earth as a Cosmic Body; A Cross Age Study." Science Education 63.1 (1979): 83-93.

In this study, the researcher individually interviewed five groups of 48 subjects from grades four to eight or a total of 240 children in Jerusalem. The major findings were that this present study supported previous studies that displayed evidence that the earth concept develops with age. In this development within the individual, there is a series of transitions from the most egocentric to some partially egocentric ones, and finally to the scientifically compatible ones.

Renner, John W., Rosalie M. Grant, and Joan Sutherland. "Content and Concrete Thought." Science Education 62.2 (1978): 215-221.

This study, using a sample of 588 Oklahoma students grades seven through twelve, administered six tasks and showed that the majority of the students thought at the concrete operational level. In the discussion, the researchers suggested that as Piaget has stated, two of the criteria that promote intellectual development are experience and social transmission. Therefore, if concrete operational thinkers utilize what they need - concrete objects, events and situations - not only will they be learning about these factors, but they will be gaining experience. Also, if the learners are permitted to relate to others about their experiences, they will be engaging in social transmission.

Wavering, Michael J., Bruce Perry, Linda J. Kelsey, and Donald Birdd. "Performance of Students in Grades Six Nine and Twelve on Five Logical, Spatial and Formal Tasks." Journal of Research in Science Teaching 3.4 (1986): 321-333.

The purpose of this study was to investigate the use of specific concrete and formal mental stuctures. Students answered questions on five tasks which allowed the researchers to assess performance and make inferences about the student's logical structures. The sample consisted of 101 students randomly selected from students enrolled at a laboratory school.

The results indicated that as the level of difficulty increased toward the formal level, there were fewer students that scored. The number of scores at the highest level on all but one of the tasks was low. The researchers included some implications from their study, e.g. classroom activities which require understanding and use of perspective cause great difficulty for students in middle and high school.

LEARNING OF SCIENCE CONCEPTS

Cantu, Luis L. and J. Dudley Herron. "Concrete and Formal Piagetian Stages and Science Concept Attainment." Journal of Research in Science Teaching 15.2 (1978): 135-143.

The purpose of this study was to investigate an instructional strategy for teaching concrete and formal science concepts. The researchers used a small sample of chemistry students. The data clearly indicated that formal operatonal students learn more, even when the lessons were over concrete concepts. Cantu and Herron further suggested that there are many important ideas in science, many concrete concepts, that can adequately be understood by concrete operational students. They also suggested that the instructional procedures used to teach the concepts must be carefully designed so that formal reasoning is not involved in the lesson.

Goodstein, Madeline and Ann C. Howe. "The Use of Concrete Methods in Secondary Chemistry Instruction." Journal of Research in Science Teaching 15.5 (1978): 361-366.

The hypothesis of this study was that instructional methods in which learners use concrete models and exemplars will lead to better understanding by students at both the concrete and formal operational levels of cognitive development. The topic was Stoichiometry with a sample of ninety-five students in two classes with experiemental treatment and two classes as controls.

The results did not show that any subject may be successfully taught if concrete "hands-on" methods are used. In this study the conceptual level of material to be learned was apparently too high for all but the advanced, formal level students. The results suggested that concrete level students cannot learn concepts which require advanced formal operational thinking, no matter how the concepts are taught. Also suggested was that learning of formal concepts can be enhanced for formal operational students by use of concrete models during the learning process.

Howe, Ann C. and Margaret Early. "Reading and Reasoning in ISCS Classes." Science Education 63.1 (1979): 15-23.

The focus of this study was on the reading and logical thinking abilities of average and below average students in urban schools where there was the Intermediate Science Curriculum Study (ISCS) program in use in the seventh and eighth grade classes. The textbooks used were analyzed to determine the reading level and logical thinking demanded. The students were tested at the beginning of the year in reading and logical thinking and again at the end of the year on science facts. Informal observations and other school data were also used to help formulate the results. Results showed that the reading level of the text was higher than the level of the students and that reasoning at the formal operational level was necessary for understanding many of the experiments presented in the text.

Lawson, Anton E. and John W. Renner. "Relationships of Science Subject Matter and Developmental Levels of Learners." Journal of Research in Science Teaching 12.4 (1975): 347-358.

The primary objective of this study was to assess understanding of concrete and formal operational concept by concrete and formal operatioanl students in Biology, Chemistry, and Physic classes. The sample of Biology, Chemistry and Physics students showed that only 4.8% were formal operational thinkers; 64.8% of the Biology students were concrete operational; 92% of the Chemistry students were classsified as transitional; and 85% of the Phsyic students were transitional. The majority of the concepts taught in the three science disciplines were considered to be formal. The scores of the tests supported the premise that concrete operational students were unable to develop an understanding of formal concepts.

Lazarowitz, Reuven. "Correlation of Junior High School Students' Age, Gender, and Intelligence with Ability in Construct Classification in Biology." Journal of Research in Science Teaching 18.1 (1981): 15-22.

The purpose of this study was to investigate the correlation between the ability of junior high school students to construct classification in biology and their intelligence scores before starting instruction in this subject. The sample consisted of 365 students, 171 seventh grade students and 194 ninth grade students. The results supported the research hypothesis that the construct biology classification ability correlated significantly with the intelligence test.

Lowell, Walter E. "A Study of Hierarchical Classification in Concrete and Formal Thought." Paper presented at the annual meeting of the National Association for Research in Science Teaching (1979).

This study was concerned with classification order. The researcher wanted to explore the relationship between performance on a hierarchical classification test and the subject's developmental level as assessed by Piagetian tasks. Those students considered to be concrete operational would be expected to perform poorly on the hierarchical test. The sample consisted of 112 students randomly selected from six junior high schools and seven high schools in urban St. John's, Newfoundland. The results supported the assumption that those student with formal, abstract thinking ability would have less difficulty on the hierarchical test.

Padilla, Michael J. "Formal Operations and Middle/Junior High School Science Education." In Science and the Early Adolescent Ed. Michael J. Padilla. Washington D.C.: National Science Teachers Association, 1983.

This paper was a review of Jean Piaget's writings and research by others on formal operations and the connections between formal thinking and science achievement. In the research that Padilla reviewed, he mentioned that most of the research was conducted with high school students and high school subject matter, but suggested that it was likely that similar results would happen with middle school students. Padilla continued with ideas and theories on ways to enhance intellectual development in the classroom, emphasizing the use of concrete activities which stressed appropriate process skills.

Sayre, Steve and Daniel W. Ball. "Piagetian Cognitive Development and Achievement in Science." Journal of Research in Science Teaching 12.2 (1975): 165-174.

The purpose of this study was to investigate the relationship between scholastic grades in science of the junior and senior high school students and the ability of the students to perform formal operational tasks. The sample consisted of 419 students. The results indicated that the formal operational student tended to receive higher grades than the nonformal operational student. Also, the lower grades by the nonformal operational student may be due in part to their cognitive development stages over which they have little control. Therefore, the researchers suggested that the ability to properly determine the student's cognitive levels is necessary for effective planning and sequencing of science instruction.

Shayer, Michael and Hugh Wylan. "The Development of the Concepts of Heat and Temperature in 10-13 Year Olds." Journal of Research in Science Teaching 18.5 (1981): 419-434.

The purpose of this study was to determine which experiments, concerning heat and temperature and their related concepts, were feasible to teach to the nine and ten year old students and which experiments and concepts should best be left until the students were twelve and thirteen years of age. The findings pointed to the importance of the teacher's role for this age group. The researchers suggested that the teacher must select content which the pupil will be able to assimilate and which will also lay the foundations for the next conceptual advances.

Tobin, Kenneth G. and William Capie. "The Effects of Student Engagement Rate, Formal Reasoning Ability and Locus of Control on Middle School Science Achievement." Paper presented at the Annual Conference of the Eastern Educational Research Association (March, 1980).

The purpose of this study was to investigate student variables that were likely to influence process skill learning. The sample consisted of thirteen classes from four middle schools in Georgia. The findings emphasized the importance of formal reasoning to achievement in science. The results indicated that the students may be limited in their ability to learn integrated process skills by low formal reasoning ability. Therefore, the researchers suggested that teachers should be aware that the majority of middle school students will have difficulty in learning to use integrated process skills. The results also indicated that by increasing attending behavior of students and providing more time for generalizing, achievement is influenced.

Yeany, Russell H., Kueh Chin Yap and Michael J. Padilla. "Analyzing Hierarchical Relationships Among Modes of Cognitive Reasoning and Integrated Process Skills" Journal of Research in Science Teaching 3.4 (1986): 271-291.

The purpose of this paper was to extend the work of the earlier researchers by looking for prerequisite relationships among the abilities which comprise formal thinking ability and the integrated science process skills. The sample consisted of 741 science students from grades seven through twelve. The results suggested that students may not be able to acquire scientific process abilities until prerequisite cognitive skills are developed.

THE POSSIBILITY OF FOSTERING INTELLECTUAL DEVELOPMENT

Chiappetta, Eugene L. and Michael J. Russell. "The Relationship Among Logical Thinking, Problem Solving Instruction, and Knowledge and Application of Earth Science Subject Matter." Science Education 66.1 (1982): 85-93.

The intent of the study was to analyze the relationship among the independent variables of the degree of logical thinking and instructional methods, which were conventional and problem solving, and the dependent variables of earth science achievement at the knowledge and application levels. The sample consisted of fourteen eighth grade earth science classes and four teachers. The time period was six weeks. The teachers were randomly assigned teaching methods of conventional or problem solving treatment. The conventional teachers were requested to ask questions at the knowledge and comprehensive level of Bloom's Taxonomy of Educational Objectives , and the lab activites simply confirmed concepts studied in the classroom. The problem solving teachers were requested to ask questions to the application and analysis levels of Bloom's Taxonomy and the lab was an inquiry investigation type lab. The results revealed higher achievement scores by the problem solving treatment students at the knowledge and application levels. The greatest difference between the groups was in the application level test, with the problem solving group achieving higher scores.

Howe, Ann C. and Janice Mierzwa. "Promoting the Development of Logical Thinking in the Classroom." Journal of Research in Science Teaching 14.5 (1977): 467-472.

The purpose of this study was to determine whether the level of logical thinking, as indicated by performance on a task requiring control of variables, of a group of low, socioeconomic status (SES), urban students could be increased through a series of instructional exercises carried out under ordinary classroom conditions. The sample of the study consisted of 62 students with average age of 13.3.

The researchers concluded that appropriate classroom instruction can increase the level of logical thinking of low, SES, urban, eighth grade students. They also showed that the gain is retained over a six-week period.

Lawson, Anton E. "The Relative Responsiveness of Concrete Operational Seventh Grade and College Students to Science Instruction." Journal of Research in Science Teaching 19.1 (1982): 63-77.

This study investigated the differences in response to instruction of two groups- concrete operational, college students and concrete operational, seventh-grade students- in two aspects of science reasoning: probabilistic and correlational reasoning. Both classes were instructed seven class periods with a learning approach of exploration, invention and discovery - SCIS.

The results indicated that the college students were more responsive. The researcher suggested the results could be because there possibly is an increase in processing space (working memory) during adolescence, enabling the college students to deal better with complex information. He also suggested the differences could be due to additional experiences. Finally, the author suggested that intensive training for the concrete operational seventh grade students may at least for some be premature and should be delayed or at least made less intensive.

Lawson, Anton E. and Warren T. Wollman. "Encourageing the Transition from Concrete to Formal Cognitive Functioning - An Experiment." Journal of Research in Science Teaching 13.5 (1976): 413-430.

This study investigated the question: Can instuction affect the transition from concrete to formal cognitive functioning in fifth and seventh grade students in one particular aspect of formal thought, the ability to isolate control variables, and will this transfer to tasks involving control of variable and novel material and tasks involving different formal concepts? The results suggested that instruction can affect transition to formal thinking in this one aspect of formal thought, and it can be transfered to tasks involving the same aspect with new materials but it can not transfer to tasks of different formal concepts. The researchers suggested there is a need for a very gradual introduction and continued reintroduction of lessons involving concrete materials and activities which enable the students to make comparisons and to make judgements on the basis of their comparisons.

Raven, Ronald J. "Programming Piaget's Logical Operations for Science Inquiry and Concept Attainment." Journal of Research in Science Teaching 11.3 (1974): 251-261.

The author discussed the research done by himself and his students concerning the facilitation of logical operation in elementary school and junior high school students. The overall results of these investigations indicated that achievement on tasks using Piaget's logical operations can be facilitated through the use of structured or programmed instruction techniques. The paper included a discussion of Piaget's stages of intellectual development and the nature of Piaget's logical operations and concluded with some implications reached from his research for science education.

Schneider, Livingston S and John W. Renner. "Concrete and Formal Teaching." Journal of Research in Science Teaching 17.6 (1980): 503-517.

The purpose of this study was to explore the idea that students experiencing inquiry teaching compared to students experiencing exposition teaching should show significantly greater gains in intellectual development and should also develop increased understanding of the content being taught. The sample consisted of forty-eight students; twenty-three were in the inquiry group and twenty-five were in the exposition group. The experiment lasted twelve weeks during which concepts to be learned were those requiring concrete operational thinking only. The concepts were the same for each group. The instruction method was different. The results supported the hypothesis strongly indicating the need for actual first hand experiences to build mental structures necessary to understand science concepts.

Wollman, Warren T. and Anton E.Lawson. "The Influence on Proportional Reasoning in Seventh Graders." Journal of Research in Science Teaching 15.3 (1978): 227-232.

The purpose of this study was to determine which type of training resulted in development of proportional reasoning in seventh grade students. The sample consisted of twenty-eight students divided into an active group in which physical materials were employed and a verbal group where standard textbook procedures were employed. The results demonstrated superiority of the active group. From these results, the researchers suggested that the students need concrete, flexible, action-oriented instruction with manipulation materials so the students can actually "see" the science principle operate.

WAYS TO PROMOTE INTELLECTUAL DEVELOPMENT
THROUGH TEACHING STRATEGIES AND METHODS

Bratt,Marvin. "The Psychological Basis for Science and Mathematical Curriculum." School Science and Mathematics 80.11 (1980): 542-548.

By using the example of two adolescents that were very different, the author illustrated what can happen to the students in a typical school environment. He revealed different teacher approaches and teacher styles and then suggested that with certain changes most students would be able to learn. He stated that sufficient evidence exists to indicate that children learn better and more productively in an environment rich in hands-on experiences. The author also boldly stated that the critical element in determining whether children learn is probably the teacher, rather than the curriculum.

Jones, Robert S. and C. Kenneth McEwin. "Creative Learning Environments for the Middle School." In Science and the Early Adolescent Ed. Michael J. Padilla. Washington D.C.: National Science Teachers Association, 1983.

The authors discussed the importance of the environment on the learning of the middle school student. Calling these students transescents, the authors stated that to learn, the transescents needed to touch, explore and manipulate. Therefore, there is need for ample space for these activities to take place. These students learn through interaction with their peers. Therefore, there is a need for small group activities and a space designed for such activities. The students learn through reading, making a need for area designed for reading, with libaries available. Learning takes place through seeing, listening, role-playing and fantasy. Places need to be planned for these kinds of activities. Transescents learn through independent thinking and investigation, so there is a need for a quiet place for individual study. Natural and created environments are needed for the students to explore. Large areas are needed for release of the substantial amounts of energy in these youth. Finally, the authors reminded us of the great variance in development, needs and learning styles of the students, demanding environments flexible enough to respond to individual differences.

Padilla, Michael J. "Science Activities - For Thinking." In Science and the Early Adolescent Ed. Michael J. Padilla. Washington D.C.: National Science Teachers Association, 1983.

This paper strongly emphasized the importance of first-hand, manipulative experiences for the student to better understand and retain knowledge. The author stated the important issues of Piagetian theory and further evidence from other researchers concerning the onset and development of formal operational abilities. He then discussed the kinds of activities needed to help students learn to think for themselves. The "recipe lab," he suggested, did little to stimulate thinking. Rather there should be activities that begin with a question or problem and ask the student to participate in finding the solution.

The remainder of the paper was concerned with the learning of process skills and activities to implement the learning of process skills. The author stated that although the research is unclear, through the use of process skills activities, there is development of formal reasoning abilities in middle school students.

Ryman, Don. "Teaching Methods, Intelligence and Gender Factors in Pupil Achievement on a Classification task." Journal of Research in Science Teaching 14.5 (1977): 401-409.

The purpose of this study was to determine if the teaching method, level of intelligence and gender are factors affecting the achievement on a task involving the hierarchical classification of drawings of living organisms. The sample consisted of ninety-six pupils divided into groups taught by traditional and modern methods. The findings, according to the researcher, could be used to support the view that pupils should be taught biology in relatively homogeneous groups in terms of intelligence level and gender. The researcher felt that the main implication of the study was that teachers of the middle school need to adapt their teaching methods and courses to stages of cognitive development and individual learning styles.

Williams, Harvey, C. William Turner, Lucien Debreuil, John Fast, and John Berestiansky. "Designing Science Lessons To Promote Cognitive Growth." In Science and the Early Adolescent Ed. Michael J. Padilla. Washington D.C.: National Science Teachers Association, 1983.

This paper thoroughly discussed Piaget's theory of cognitive development, especially figurative and operative knowledge and perception and logical operations. The authors have devised science learning activities, specifically designed to provide operative learning experiences. According to the authors, operative learning occurs only when a student solves a problem or finds an answer by his or her own reasoning. Therefore, an operative learning experience is possible only if the learner is actively engaged in thinking. Motivation is a very important factor. Most students have been conditioned to wait for the teacher to tell them the answer. It will, therefore, require interesting situations and appropriate teacher responses to motivate the students to think for themselves.

Yeotis, Catherine and Alice Hosticka. "Promoting the Transition to Formal Thought Through the Development of Problem Solving Skills in Middle School Mathematics and Science Curriculum." School Science and Mathematics 80.11 (1980): 557-565.

In this paper the authors began by discussing Piaget's model of two types of operational thought, the concrete operatonal and the formal operatonal. In relating research showing that even as much as 75% of the college freshmen are not demonstrating formal operational abilities, the authors stressed the importance of an environment specifically designed to aid transition from concrete to formal operations. The authors suggested that the middle school is where there should be major emphasis on development of problem solving skills using symbolic representation and information processing skills to ease transformation from concrete to formal thought. They maintained that problem solving skills provide a vehicle for teaching critical thinking skills.

SUMMARY

Lawson (1979), in a study using eleven - thirteen year old students administering three tasks- the chemical combination task, bending rod task, and balance beam task- lent support to Piaget's hypothesis that this age begins formal thinking. He also found there was a wide range of diversity in this age group. A year earlier Lawson, Karplus and Adi published a study which sampled 507 students, spanning an age range of 11.5 to 20 years. They administered a seven-item, pencil-paper test, five items requiring formal operational schemata of proportions, probability and correlations and two items requiring use of common rules of propostional logic. The results showed an increase in success with increase in school grade, supporting a developmental perspective of acquisition of formal schemata. The study by Nussbaum of children from fourth to eighth grade of the child's concept of the earth as a cosmic body showed evidence that the earth concept developed with age. The development "and change in notions are conceived as acts of cognitive accomodation taken by the child in order to make possible a better assimmilation of the encountered scientific information."(Nussbaum, 1979, p. 93.)

In 1974 Lawson and Renner, using a battery of six, Piagetian-styled tasks, showed an extremely larger percentage of students, seventh grade through twelvth grade, responding concretely, illustrating a differing view from Piaget in the age at which an individual enters the formal operational stages. They further substantiated this with another study of college freshmen

resulting in only 22% demonstrating in the formal operational stage. Kolodiy reinforced the theory that high school and even college students were not operating on a formal operations level, since his study illustrated that some 30% of students graduating with science degrees were still not operating at the formal level. In a review of Piagetian studies by Chiappetta, he stated that 77% to 83.4% of junior high school students were subjects at the concrete operational level.

The study by Karplus, Karplus, Formisano and Paulsen tested thirteen - fifteen year olds in seven countries; Denmark, Sweden, Italy, U.S., Austria, Germany, and Great Britain. Using proportional reasoning problems and controlling variable problems, about 25% of the subjects used formal operations on proportional reasoning and 20% used formal operations on controlling variables. The researchers concluded that the science and mathematical program used in each country influenced the likelihood of demonstrating formal reasoning ability to some degree. Renner, Grant and Sutherland tested students grades seven - twelve with results that only 17% of the seventh grade students, 23% of eigth grade students and 34% of the twelth grade students demonstrated formal operational level of thought. A more recent study, which Wavering, Perry, Kelsey and Birdd designed to test the performance of students from grades six, nine and twelve on five logical, spatial, and formal tasks, again demonstrated that few students accomplished the formal level of thinking.

If many students do not perform on the formal level of

thinking, are the concepts and ideas being taught in middle school science requiring formal thinking skills? If the concepts are formal, are concrete operational students able to comprehend and learn these concepts?

In Howe and Early's investigation of the Intermediate Science Curriculum Study in 1979, the results indicated that many of the problems and hypotheses presented in the text were at a formal operational level, and therefore, seventh and eighth grade students would have difficulty comprehending and learning. Lawson and Renner (1975), when dividing science concepts into concrete concepts and formal concepts, found that the majority of concepts at high school and college level were abstract in nature. The main purpose of their study was to assess the understanding of concrete and formal operational concepts by concrete and formal operational students. Their results showed that concrete operational students were unable to develop an understanding of formal concepts. Cantu and Herron clearly demonstrated that formal operational students learn more, even when the lessons are over concrete concepts. They also showed that concrete operational students learned concrete concepts when instruction procedures used to teach the concepts were carefully designed, so that formal reasoning was not involved in the lesson. Goodstein and Howe's results also suggested that the concrete level students could not learn concepts requiring formal operational thinking, and formal operational students could learn formal operational concepts better when use of concrete models were a part of the

learning process. The studies by Lawson and Renner, Cantu and Herron, and Goodstein and Howe were conducted with high school students and high school matter, but as suggested by Padilla (Formal Operations, 1983), it is likely that similar results would occur with children aged ten - fourteen.

Shayer and Wylan researched the specific concepts of heat and temperature with ten - thirteen year olds. They suggested that because some of the concepts, such as calorimetric concepts, would not be understood until early formal thinking, the teacher's role for this age group would be to select content which the students are capable of assimilating, thus laying the foundations for the next conceptual advances.

The study by Lazarowitz correlating the ability of students in the junior high to construct classication biology to their intelligence scores, indicated that a great part of the variance in biological classification ability was attributed to general intelligence. Therefore, the teacher could, through pretesting, determine students' weaknesses and strong points and plan suitable curriculum. Lowell, using a hierarchical classification test and Piagetian task tests, first showed that his sample for grades seven - eight were 88,5% concrete, 11.5% transitional, and none in the formal range. Another sample for grades nine, ten, eleven were 70% concrete, 16.7% transitional and 13.3% formal. Those students in the formal level scored higher in the classification tests, showing that individuals dependent on concrete cues showed much less success with ability to organize information in hierarchical classifications. An early study by Sayre and Ball in

1975 indicated that the junior high school student operating on formal level thinking received significantly higher grades than nonformal students. Tobin and Capie also illustrated the importance of formal reasoning to achievement in science. They particularly discussed the difficulty of middle school students in learning to use integrated process skills. The student's ability to learn integrated process skills, according to Tobin and Capie, is limited by low formal reasoning ability. In 1986, Yeany, Yap and Padilla also showed results from their research that students may not be able to acquire scientific process abilities until they develop prerequisite cognitive skills. According to the researchers, students reasoning at the concrete level do not master abstract science concepts.

If many science concepts are abstract in nature but most middle school students are unable to understand those concepts because they are concrete operational, is it possible to foster intellectual development and lead the concrete thinker to more formal thought processes, and therefore, move the students closer to understanding the more formal science concepts?

Raven asked the question: Through program instruction techniques, can Piaget's logical operations be used to achieve tasks? He restated Piaget's idea of assisting the students by helping children to manipulate the parts of a concept and then putting them together in different ways. His results showed that the use of structured training materials was found to enhance the

achievement of pupils on logical operations tasks. Lawson and Wollman explored the issue, particularly the ability to isolate contol variables, with fifth and seventh grade students. They also asked the question: If training can enable concrete students to perform at formal levels on tasks used in the training phase, will they transfer to tasks using new materials involving control of variables? Their results showed that they could use instructional procedures and successfully affect the transition from concrete to formal cognitive functioning in regard to controlling variables but did not show that it would transfer to tasks of different concepts involving formal thought. They also showed that the more formal the student, the more receptive the student was to training.

Howe and Mierzwa reported on an attempt to use classroom instruction to raise the level of logical thinking in students. They used sixty-two students of low, socioeconomic status, urban schools. Their conclusions were that appropriate classroom instructions can increase the level of logical thinking in the student, and that the gain is retained over a six week period. They were performing tasks requiring the control of variables. Wollman and Lawson looked at ways to successfully teach the concept of proportions. One group of seventh graders was an active group in which physical materials were employed. The other group was a verbal group, where standard textbook procedures were used. The results showed that the active group was superior to the verbal group in the posttest. They suggested that in teaching the concepts and improving the reasoning, it was important that

> Instruction parallel the process of internalization involving working with the principle in concrete, flexible, action-oriented contexts, actually "seeing" the principle operate. Then students could be supplied with symbolic representation which would progressively be internalized by reducing the need for concrete supports. (Wollman and Lawson,1978,p. 232.)

In 1982 Chiapetta and Russell demonstrated that through instruction using problem solving techniques and inquiry labs, the students performed better, especially with increase on application level showing the use of logical thinking. Their sample included 287 eighth grade students in earth science for six weeks. Half the students were instructed with conventional methods. The teachers were requested to ask questions at the knowledge and comprehensive level of Bloom's Taxonomy of Educational Objectives, and the lab activities confirmed concepts studied in the classroom. The other half were instructed with problem-solving techniques. The teachers were requested to ask questions to the application and analysis levels of Bloom's Taxonomy, and the labs were three step: presenting the problem, formulating inquiries and gathering information, and analyzing of information to discover relationships for solving the problems.

The study by Schneider, Livingston and Renner compared inquiry teaching or concrete instruction and exposition teaching or formal instruction. The result showed the superiority of the concrete instruction in promoting intellectual development in the concrete operational student. In the study by Lawson in 1982, the results implied that intensive training of concrete operational seventh grade students might at least for some students be premature and might be more successful if delayed or made less

intensive.

With some research showing that formal thinking may be increased with appropriate instruction, what are the different ways to promote intellectual development in the classroom?

In Kolodiy's study, findings suggested that there is a wide variability in cognitive functioning among students. Therefore, he suggested that learning experiences needed to be oriented more toward the individual. A need was shown for more concrete activities, with students having hands-on experiences and discussions among themselves. With this interaction among students, some with higher levels of thinking, the students experience disequilibrium and are provided with necessary experiences for accomodation to take place. Bratt also emphasized the importance of an environment rich in hands-on experiences. He also strongly stated that the teacher rather than the curriculum was the critical element in determining whether the student will learn. The article by Yeotis and Hosticka suggested that the middle school is where there should be major emphasis on development of problem-solving skills, using symbolic representation and information processing skills to ease transformation from concrete to formal thought. From a study by Ryman which showed a difference in achievement with difference in instruction, he suggested a need for more homogeneous grouping in terms of intelligence levels.

Williams, Turner, Debreuil, Fast and Berestiansky suggested

using science activities designed specifically to provide operatve learning experiences. They suggested operative learning occurred only when a student solved a problem or found an answer by his or her own reasoning. An interesting situation would be required in which the teacher would pose a problem or ask a question that would challenge the learners to arrive at a solution or answer that would make sense to them. The learner would be actively engaged in thinking. The importance of motivation was stressed because the experiences would be less satisfying to the students conditioned in figurative operative learning traditions.

Jones and McEwin suggested it was very important that middle schools realized that the students had not reached formal stage of intellectual growth. They needed an environment where they could explore freely, where they could be aware of the consequences of their behavior, and where they could learn at their own rates. They stated that these students learned through doing; therefore, the students needed space to explore, manipulate and experiment. The students would learn through conversing; therefore, there was a need for small groups. The students learned through reading; therefore, they needed space and time for that activity. The students learned through seeing and listening, through role-playing and fantasy; therefore, the schools should provide these experiences. The students learned through independent thinking and investigation, through exploring natural and created environments and through vigorous body movement. The authors continued by stating that the students vary greatly in their development, their needs and their learning styles.

Through the use of process skills activities over a long period of time, Padilla suggested that the middle school student may develop formal reasoning abilities. He stated that when the "recipe lab" approach is used, the students performed specific steps to prove a statement of the teacher or text with litle stimulation of thinking. He suggested, rather, that there should be activities that ask a question or pose a problem for the students to solve. The method of obtaining the solution should be stressed more than the solution. He did, however, stress the importance of avoidance of abstract topics in the development of the process skills activities.

Finally Lawson and Wollman in their study added still another technique when they suggested a need for gradual introduction and continued reintroduction of lessons involving concrete materials and activities which enable the students to make comparisons and to make judgements on the basis of their comparisons. They continued to stress that the teacher would need to allow the student to make mistakes and then critically reflect upon those mistakes.

CONCLUSION

The research results reviewed above point to several conclusions for the middle school teachers. First of all, the research demonstrates that the middle school student, ages eleven - fourteen, rarely shows formal thinking ability. Rather these students are concrete operational or transitional between concrete and formal thinking. The concrete middle school student will have great difficulty comprehending abstract science concepts. Much of science concepts are abstract, and the teaching strategies of teacher lecture and demonstration are formal teaching strategies. Using these teaching strategies, the student does not learn as well as when the teacher uses concrete teaching strategies of hands-on experiences and inquiry investigations.

There can be a fostering of intellectual development through various teaching strategies. However, the research is limited and the strategies vary to the extent that conclusions are not readily made. There is a need for more research in this area of science instruction.

RECOMMENDATIONS

It is recommended that :

1. Middle school teachers be aware that middle school students are mostly concrete operational or transitional between formal and concrete operational. However, very few have formal thinking ability.
2. Science teachers realize that students who are concrete oriented are unable to understand and comprehend abstract science concepts.
3. Science teachers use concrete teaching strategies to allow students to learn. This involves hands-on experiences and inquiry investigations rather than rote memorization of science facts.
4. A review of science curriculum topics be made and the formal, abstract topics postponed until a later age.
5. Science teachers use teaching strategies that foster intellectual development with instruction of problem solving techniques, and that they question students to the application and analysis levels of Bloom's taxonomy through the use of inquiry labs.
6. Further research be done on strategies to enhance intellectual development.
7. The middle school provide ample space for movement allowing for exploration, manipulation, and experimentation.

8. Teachers make use of small groups so students have opportunities for peer group discussions allowing assimilation and accommodation to take place.
9. Because of the great degree of variability at this age, the teacher must plan learning environments that are flexible enough to respond to individual differences.

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